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Sirius Satellite Radio Inc.
XM Radio Inc.

November 1, 2001

BY HAND

Ms. Magalie Roman Salas, Secretary
Federal Communications Commission
The Portals
445 Twelfth Street, S.W.
12th Street Lobby, TW-A325
Washington, DC 20554

Re: Written Ex Parte Presentation
1998 Biennial Regulatory Review — Amendment of Part 18 of the Commission's Rules to Update Regulations for RF Lighting Devices (ET Docket No. 98-42)

Dear Ms. Salas:

There have been several past meetings on the subject of interference by radio frequency ("RF") lighting into SDARS receivers attended by the Commission staff, Sirius Satellite Radio Inc. ("Sirius"), XM Radio Inc. ("XM") and Fusion Lighting, Inc ("Fusion"). In some of the meetings, Sirius and XM have questioned whether the out-of-band emission levels from RF lights could be reduced by different or improved construction of the lamps. Fusion answered that either this was not feasible or not economic.

Sirius has hired an expert consultant, John M. Osepchuk, PhD, to investigate this question. His resume is provided in Attachment 1. His investigation yielded two specific areas where different or improved construction should reduce RF lighting out-of-band emission levels in a practical and economic manner:

- improved screen design, especially using a dual screen approach, and
- different power supplies, particularly the half-wave doubler supply which can be implemented at this time.

Dr. Osepchuk's examination suggests that there are inexpensive and practical methods that Fusion could employ to redesign its magnetron to reduce dramatically interference into adjacent channel services such as SDARS.

The full Statements on these two results of the consultant's investigation are provided in Attachment 2. Sirius and XM request that the Commission take these results into consideration when reviewing the rules applicable to licensing RF lighting.

If there are any technical questions about the foregoing, please call Robert D. Briskman, Technical Executive, at Sirius. Mr. Briskman's phone number is (212) 584-5210.

Sincerely,

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ATTACHMENT 1

Biographical Sketch

Osepchuk, John M.; Independent Consultant; <u>Full Spectrum Consulting,</u> 248 Deacon Haynes Road, Concord, Ma 01742

Education: A.B.('49), Harvard College; A. M. ('50), Ph. D. ('57), Harvard University. Dr. Osepchuk worked for Raytheon Company in microwave R&D (ferrites, plasmas, tubes and heating systems). He played a leadership role in founding and operating many activities in the IEEE (life member, COMAR; SCC28, chairman; MTT-S and SIT-S); IMPI (JMP editor and president); EEA (organizer and officer); and BEMS (early member). He is a fellow of the IEEE and IMPI, a member of $\phi\beta\kappa$ and $\Sigma\xi$, and was awarded the IEEE Standards Medallion in 1998, and the IEEE Millennium Medal in 2000. He has authored many patents and publications, including a key patent on microwave-oven door-choke seal design. His present activities include studies of the microwave auditory effects, microwave heating (for Amana) and safety (for Cingular Wireless and others). He is leading the effort to strengthen the global influence of IEEE, through the International Committee on Electromagnetic Safety (ICES) in developing international consensus standards for safe use of electromagnetic energy. He is also leading the global effort by the ISM community to resolve the RFI issues accompanying the shared use of ISM bands by wireless systems and ISM equipment.

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Dr. Osepchuk received his A. B., magna cum laude with highest honors, from Harvard College in 1949. He received A. M. and Ph. D. degrees in engineering science and applied physics from Harvard University in 1950 and 1957, respectively.

After joining Raytheon in 1950, he conducted research on ridge-waveguides and magnetrons, and helped design the first high-power backward-wave oscillator in the United States. During 1956 and 1957, he was technical liaison for Raytheon at the microwave-tube research laboratories of Compagnie Génerale de Telegraphie sans Fil at Paris, France. From 1957 to 1962 he was head of several research projects on crossed-field devices.

From 1962 to 1964, Dr. Osepchuk was chief microwave engineer for Sage Laboratories, in Natick, Massachusetts.

In 1964, Dr. Osepchuk returned to the Raytheon Research Division in Waltham, Massachusetts. He directed various projects in the field of microwaves (tubes, ferrites, plasmas) image tubes, and physical electronics. Since 1968, he consulted for Amana and other Raytheon Divisions on radiation hazards and investigated various aspects of Radarange Technology, especially those involving leakage and safety. He held a key patent on microwave-oven choke door-seal design (U. S. Pat. Re.32,664, May 10, 1988; reissue of U. S. Pat.3,767,884, Oct. 23, 1973) of considerable value to Amana in marketing and royalties. He was appointed Consulting Scientist at Raytheon in December, 1974.

Dr. Osepchuk has published and presented many papers in the fields of microwaves and radiation hazards and holds more than twenty patents. He was guest editor for the special issue (February 1971) on Biological Effects of Microwaves in the *IEEE Transactions on Microwave Theory and Techniques*. He was editor of the *Journal of Microwave Power* (1970-1971) and is editor of the

IEEE Press volume (1983) of reprints; *Biological Effects of Electromagnetic Radiation*. He is the author of many articles in current encyclopedia editions or handbooks in the subject areas of microwave safety standards and microwave power applications.

Dr. Osepchuk was National Lecturer (for 1977-1978) of the MTT Society (IEEE) on "Microwave Radiation Hazards in Perspective." In addition he was the General Chairman of the 1978 Symposium on Electromagnetic Fields in Biological Systems, which was co-sponsored by the IEEE MTT-S and IMPI. He was on the Program Committee and a Session Chairman for a Symposium on "Health Aspects of Non-Ionizing Radiation" which was held on April 9 - 10, 1979 under the sponsorship of the New York Academy of Medicine.

Dr. Osepchuk is a Life Fellow of the IEEE and the International Microwave Power Institute (IMPI) and a member of Phi Beta Kappa, Sigma Xi and the Bioelectromagnetics Society. He is past chairman of the Boston Section of the IRE Professional Group on Electron Devices, a past member of the National Administrative Committees of two IEEE societies: those on Microwave Theory and Techniques as well as Social Implications of Technology. He has held various offices in the standards community (C95 and IEEE SCC28 committees), the appliance industry (Association of Home Appliance Manufacturers) and the microwave power profession, including President of IMPI for 1992-1995.

In the early 1980's, he helped organize seminars for medical, legal and executive personnel on effects and hazards of electromagnetic energy (the Homestead Seminars). In 1983 Dr. Osepchuk chaired a committee which led to the formation of the Electromagnetic Energy Policy Alliance (EEPA). (Now called the Electromagnetic Energy Association, EEA). This Alliance was founded by eight leading manufacturers and users of electromagnetic energy and was aimed at technical and public information activities which enhance a rational perspective towards electromagnetic energy associated with electricity and electronics. EEA publishes facts sheets and position statements, newsletters and holds a short course and symposia aperiodically.

In 1995, Dr. Osepchuk retired from Raytheon Company. Since then, he has been an independent consultant practicing under the name of Full Spectrum Consulting with office and laboratory in Concord, Massachusetts. Presently, he conducts research on the microwave auditory effect, microwave ovens and magnetrons, microwave power systems (heating, discharges...), microwave interference and microwave hazards. He is presently an advisor to the Board of Directors of EEA, a corresponding Board Member of IMPI, a Life Member of COMAR, the Chairman of the IEEE International Committee on Electromagnetic Safety (ICES-SCC28 Standards Committee), a member of the IEC TC-106 committee on assessment of EM fields relative to safety and a member of the U. S. TAG (Technical Advisory Group) for the CISPR committee which develops international specifications on interference. In 1998, he was awarded the Standards Medallion by the IEEE for leadership in SCC28 and contributions to standards for the safe use of electromagnetic energy. In 2000, he was awarded the Millennium Medal by the IEEE. His clients include Amana Appliances and Cingular Wireless. In addition, Dr. Osepchuk lectures on occasion at university courses and professional meetings on the general area of bioeffects and hazards of electromagnetic energy. He also consults in some cases of litigation involving siting ,or liability aspects of systems using electromagnetic energy.

Dr. Osepchuk is involved in the leadership of two global movements:

1. The continuing evolution of an international interdisciplinary community for the development of broad-consensus standards for the safe use of electromagnetic energy under the due process and open procedures of the IEEE International Committee on Electromagnetic Safety (ICES-through SCC-28 and SCC-34). This is a prerequisite for the rational development of electromagnetic technology and is to be preferred over the reliance on closed elite committees or the adoption of the *Precautionary Principle*, which is tantamount to the rejection of science.

2. The dialogue between the ISM (IMPI) and wireless communities to resolve RFI problems encountered in the co-use of ISM bands with the goal of preserving the benefits of inexpensive efficient use of microwave power. These microwave-power applications are in their infancy except for the now well-accepted microwave oven and a *few* industrial applications. Thus it is important to preserve beneficial emerging applications in both the wireless and power applications areas. This will require a well-balanced political, as well as technical, approach.

ATTACHMENT 2

Statement on
Possibilities in Screen Design for Microwave Lights of Value for Mitigation of Noise in the 2.3 GHz Band

This document explores the possibilities of reducing emissions in the 2.3 GHz band from microwave-excited lights by introducing innovations in screen design. The most promising possibility is based on the introduction of two screens in cascade separated by an optimum distance for maximum suppression of the emission of concern.

Introduction:

There exists concern that microwave-excited lights (lamps or lighting devices) may emit energy in the 2.3 GHz band (actually 2.32 – 2.345GHz) that will interfere with the reception of microwave digital audio broadcast signals from satellites, even if the lights meet the existing requirements by the FCC or CISPR on out-of-band emissions. The microwave lights are an ISM (Industrial, Scientific and Medical) device designed to operate in the ISM band of 2.4 GHz – 2.5 GHz—the same band in which microwave ovens operate. The microwave lights utilize the same or similar magnetrons as used in the microwave oven. The magnetron is the ideal source for these power (non-communication) applications because of their high efficiency (>70 %) and their low cost (~$10 for large-scale manufacture of microwave ovens). The magnetron also, however, generates a high level of noise and spurious signals in addition to the fundamental signal and its harmonics. This out-of-band energy appears as sidebands to the fundamental and harmonic frequencies, radiated from the front as well as back sides of the oven or lights, as well as base-band energy radiated from the back side-where the magnetron is located with a more direct path to the electricity power cord. The sideband region is roughly from 50 to 400 MHz from the carrier (fundamental signal of 2.45 GHz) with a maximum typically between 150 and 300 MHz from the carrier. The energy is complicated by its variation in amplitude and frequency with the instantaneous anode current of the magnetron which for practical ovens and lights varies from – to some maximum value cyclically at the power line frequency of 60 (or 50) Hz.

In the 2.3 GHz band most of the energy is emitted (leaked) from the front end—where the oven door is present or the output screen of a microwave light. Furthermore increase of suppression of 2.3 GHz energy from the back end involves mostly cost considerations but no fundamental conflict with the performance of the lights. At the front end of the lights, however, on some designs, the same mesh screen which helps contain the microwave energy also must be highly transparent to the light as well as allowing the exhaust of cooling air which after cooling the quartz light bulb then helps cool the metal screen. Since the screen is the largest source of microwave emissions in these lights, it is worthwhile to review the possibility of design modification of such screens to attain maximum suppression of microwave leakage, particularly that in the 2.3 GHz band.

It must be remembered that although the present objective is to minimize emissions at 2.3 GHz, in the end one must also check the effect of design modifications on emissions across the whole spectrum. Although one cannot make absolute judgments, there is reason to believe that some of the possible design modifications under consideration will not seriously affect emissions at other parts of the spectrum of importance relative to potential interference with other services.

Design of Screens for Microwave Suppression:

Metal screens or meshes are used to permit the exit of the desired light energy as well as contain the microwave energy in the light enclosure, containing a spinning quartz lamp (containing a gas including sulfur components). The screen intercepts unavoidably some light energy, which can contribute to heating the screen. Thus the screen must allow the exhaust of air, which also performs a cooling function on the screen.

We here review only the function of the screen for microwave suppression and explore the potential for maximizing this suppression by redesign of the screen dimensions. The suppression of microwave transmission through the screen can be estimated for a mesh of round wires by the formula of Mumford [1], viz.:

$$P_0/P_l = B^2/4 \qquad (1)$$

Where P_0 is the power or power density impinging or incident on the screen and P_l is the power or power density transmitted through the screen and

$$B = \frac{\lambda}{a \ln \{0.83\exp 2\pi r/a\}/[(\exp 2\pi r/a)-1]} \qquad (2)$$

and λ is the wavelength, a is the period between wires and r is the radius of the wire. The wire is assumed perfectly conducting.

Another useful formula is that of Otoshi [2] for the transmission loss T in dB:

$$T = 20 \log \{3ab\lambda/(2\pi d^3 \cos\theta_i)\} + 32t/d \qquad (3)$$

Where a and b are the two distances between centers of any array of holes in the screen, d is the diameter of the holes, t is the thickness of the screen, θ_i is the angle of incidence on the screen and λ is the wavelength. (~12.9 cm)

If we assume screens with basic periods of around 0.100" these formulas yield suppression factors of 27 to 40 dB, roughly, for screens of 80 to 90 % optical transparency. In both cases if we halve the period and also scale the diameters and thicknesses we gain 6 dB. Therefore to get substantial increase in suppression—say 20 dB, we need to reduce the period by a factor of 10 or more. Such fine screens, with a period of only 0.010" are feasible but expensive and fragile if self-supported (e.g. as available from Buckbee-Mears, Inc.). On the other hand such screens are feasible if deposited on a dielectric substrate [3]. These are feasible for use in microwave ovens but pose serious problems in the light application because of the heating of the substrate by the intense light and the blocking of airflow. Even if the airflow is then effected through an additional array of ventilation holes (not designed for light output) this then complicates the design of the whole device.

We note from formula (2) that doubling of screen thickness from t/d = 0.25 to 0.50 results in only an 8 dB increase while increasing significantly the difficulty in screen manufacture—whether deposited or self-supporting.

We conclude that modest increase in screen suppression (e.g. 6 to 10 dB) is feasible in microwave lights, but some new approach is required for substantial (e.g. 20 dB or more).

A Cascade Design:

The potential for substantial suppression increase is seen if one considers arranging for two screens in cascade at the output aperture of the microwave light. These must not be closely located for then they perform more like a thickened screen. But if they are separated by a significant fraction of a wavelength, then they will act to double the total transmission in dB. From simple transmission-line theory [4] one can estimate the optimum separation as roughly $\lambda/4$—i.e. a quarter wavelength while a separation of $\lambda/2$ would create a near-resonant condition with maximum transmission.

In the case of the microwave light the output aperture diameter is of the order of a few inches. Thus at 2.3 GHz only a few modes would propagate in the circular pipe (or flared pipe) that connects the two screens. The cutoff wavelength for the fundamental mode is 3.42 a where a is the radius of the pipe and is expected to be much larger than the free-space wavelength at 2.3 GHz. All the other modes must be analyzed, as well and a screen separation determined that is roughly $\lambda_g/4$ for all modes at 2.3 GHz, where λ_g is the guide wavelength for a given mode. At least the separation should not be close to $\lambda_g/2$ for any mode.

It would appear that it should be feasible to carry out such a design for doubling or substantially increasing the leakage suppression, in dB, at 2.3 GHz and frequencies nearby. In principle the suppression improvement may be less satisfactory at other frequencies far from 2.3 GHz. Still because practical concern centers heavily in the range of 2 to 3 GHz, the outlook is promising.

There remain the questions of effect of the design modification on optical transmission and airflow. Both these parameters suffer a modest decrease in performance if the two screens are like an initial design of modest optical transmission –e.g. 80 %. This possibly could be mitigated by introducing screens of higher optical transmission with a concomitant small decrease in microwave suppression. The combination, however, can still show substantial increase in total microwave suppression at least around 2.3 GHz.

Design for Glass Window Output:

In one design that has appeared, the quartz lamp is surrounded by a rectangular parallelepiped mesh structure that contains the microwave energy. In this case the output window is made of glass and airflow is not required at the window. In this case very fine mesh structures can be photo deposited and high suppression achieved.

Furthermore, if necessary, there is the option of two photo deposited screens, one on each surface of the glass window, with adjustment of window thickness for optimum performance.

Conclusions:

We conclude there is a reasonable potential for substantial increase of the suppression of microwave leakage through the output screens of microwave-excited lighting devices through the use of a cascaded screen design (2 screens). A modest increase in manufacturing cost is incurred but it is believed that optical transparency and airflow functions of the screens can be maintained at acceptable levels of performance.

References:

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Prepared by:
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October 29, 2001

Statement on
Power-Supply Options and Their Relation to Mitigation of Out-of-Band Magnetron Noise in the 2.3 GHz Band

This document explores the possibilities of reducing emissions in the 2.3 GHz band from microwave-excited lights by choice of power-supply design. The most promising option, in the near future, is the use of a half-wave doubler supply.

Introduction:

There exists concern that microwave-excited lights (lamps or lighting devices) may emit energy in the 2.3 GHz band (actually 2.32 – 2.345GHz) that will interfere with the reception of microwave digital audio broadcast signals from satellites, even if the lights meet the existing requirements by the FCC or CISPR on out-of-band emissions. The microwave lights are an ISM (Industrial, Scientific and Medical) device designed to operate in the ISM band of 2.4 GHz – 2.5 GHz—the same band in which microwave ovens operate. The microwave lights utilize the same or similar magnetrons as used in the microwave oven. The magnetron is the ideal source for these power (non-communication) applications because of their high efficiency (>70 %) and their low cost (~$10 for large-scale manufacture of microwave ovens). The magnetron also, however, generates a high level of noise and spurious signals in addition to the fundamental signal and its harmonics. This out-of-band energy appears as sidebands to the fundamental and harmonic frequencies, radiated from the front as well as back sides of the oven or lights, as well as base-band energy radiated from the back side-where the magnetron is located with a more direct path to the electricity power cord. The sideband region is roughly from 50 to 400 MHz from the carrier (fundamental signal of 2.45 GHz) with a maximum typically between 150 and 300 MHz from the carrier. The energy is complicated by its variation in amplitude and frequency with the instantaneous anode current of the magnetron which for practical ovens and lights varies from – to some maximum value cyclically at the power line frequency of 60 (or 50) Hz.

Dependence of Noise on Anode Current:

It is important to realize that the magnetron used in microwave ovens and microwave lights is essentially of one standard design, regardless of the manufacturer [1]. Thus its properties, including those of noise and spurious are basically the same in all tubes. It has been shown [1] that the noise and spurious signals from this magnetron are a function of the instantaneous value of anode current, which in most applications is varied at a rate of 60 (50) Hz, except for a few ovens that utilize a switched-mode power supply [2]. In these cases, the anode current may also be varying at a rate of 20 to 100 kHz. Although it is possible to create a d.c. power supply by filtering out the a.c. in the output of the switched-mode power supply, this rarely has found practical application, primarily due to cost. In the most popular power supply, the half-wave doubler, the output is a voltage pulse approximating a square-wave pulse, once per 60 Hz (or 50 Hz) period with an accompanying pulse of anode current that appears like one half cycle of a sine wave. In the full-wave doubler power-supply, the anode current waveform is somewhat like a rectified sine wave except for small periods of zero current at the zero-crossing moments.

As shown in the literature [1], there are three regions of anode current with distinctly different noise properties. First there is the region of low anode currents, from 0 to about 200 to 400 mA, roughly, for most cooker magnetrons where broad noise peaks are generated at sideband frequencies that vary with current in this range. In particular, the lower sideband may exist between 2.00 GHz and 2.4 GHz. The net result in the ac driven cooker magnetron is appearance of substantial noise in sideband regions like 2.0 – 2.4 GHz Between roughly 400 mA and 700 mA, discrete spurious signals of considerable amplitude may exist in the sideband regions—in particular between 2.1 to 2.35 GHz. Finally above 700 mA up to the peak current which is around 1.0 Ampere, there is essentially no noise or spurious signals.

In the microwave oven with wide variation in loads and stirrer actions, the composite spectra and waveforms are very complex. In a microwave-excited lighting device, where the "cavity" is small and the mechanical stirring (of the quartz lamp) is limited, the spectra and waveforms should show less variation. Still as shown [1], the net result is that at a specific frequency and over a small band, e.g. 10 to 20 MHz, the noise or spurious signals appear as narrow (e.g. <1 msec) pulses at the beginning and the end of the conduction period (one half cycle in the case of the half-wave doubler). A more thorough study [2] of spurious signals from cooker magnetrons shows that there are some spurious signals that can exist throughout the conduction period, but these, so far, have been found to occur only at base-band frequencies < 1 GHz.

Comparison of Noise Duty Cycle with Various Power Supplies:

Thus with the half-wave doubler supply, spurious energy at 2.3 GHz will occur only for less than 2 milliseconds, at most, within one 60 Hz period, or less than 15 % of the time. In this case for 85%-90% of the time there is no interference at 2.3 GHz emitted by the microwave light,

On the other hand, with a full-wave doubler supply, there will be four such noise pulses during any one 60 Hz period. This roughly means a noise duty cycle of about 25% and noise-free duty cycle of only 75 %. The full-wave supply, in principle requires less peak current then the half-wave supply. Thus, in principle, operating life of the magnetron should be greater with the full-wave supply. In practice, this difference may be less than predicted by simple considerations. Reasons for this include differences in waveforms from simple theory—e.g. more peaked current waveforms for full-wave supplies than for half-wave supplies.

Switched-mode supplies [3], without filtering, will not yield lower noise than the simple doubler supplies. Some data [4] suggests that the noise may be even somewhat larger because of relatively larger dwell times at low currents when the currents are modulated at high rates—e.g. 80 kHz.

In principle, with filtering, which is expensive for consumer applications, the power supply can become a d.c. supply and the magnetron run at essentially constant current. e.g. 300 mA instead of 300 mA average and 1 A peak. Limited experience [5] in such operation of cooker magnetrons shows that very low noise operation is achieved. What has not been explored yet, however, is the impact on life and what requirements there may be to adjust filament current to maintain this condition during life. The theory is that the magnetron is operating temperature-limited in this case and is thus close to the mode boundary triggered by insufficient emission. (The lower mode boundary in terms of filament voltage) Complicating the question is the fact that a.c. operation of the magnetron is intrinsically different [1] from d.c. operation of the magnetron. In the a.c. case the tube operates at instantaneous currents of 0 to 1 A while the heating balance is that characteristic of 300 mA or 0.3 A. In the d.c. case the instantaneous current and average current are the same with different implications in terms of heating balance, cathode back-bombardment, secondary emission and other phenomena. Thus, for example, in d.c. operation [5] at 300 mA the optimum filament voltage is low and even zero—i.e. cathode heating purely from back-bombardment. How critical the maintenance of this condition during life has not been determined.

Thus, with a d.c. supply, although there is the promise of very low-noise, this has not been established as reliable during life. Furthermore, if the magnetron drifts into a noisy state it will produce essentially continuous noise at certain frequencies—i.e. high duty cycle. These frequencies will drift according to thermal phenomena as well as with any stirrer activity, e.g. the rotation of the quartz lamp in the microwave lighting device. We can conclude that the option of a d.c. supply has the promise of very low noise and some unresolved problems of stability and life. In view of the absence of spurious noise in the ideal performance in this mode, an in-depth investigation is warranted.

Conclusions:

We have reviewed several options of power supplies available to the designer of microwave-excited lights. Although a d.c. supply may in the future yield the lowest noise levels, further studies are needed to confirm that potential problems of life and stability can be controlled. In addition cost-reduction studies are desirable.

Of the two doubler supply options, the half-wave doubler is considered superior to the full-wave doubler because its potential noise duty cycle at 2.3 GHz is roughly half of that with the full-wave supply. Furthermore it presents only two noise periods per 60 Hz period to be avoided vs., 4 such periods in the full-wave case. This affords the designer of broadcast systems like the audio broadcast satellite system more opportunity to realize noise-free transmission and reception in the real world.

The use of the half-wave supply vs. the full-wave supply may pose theoretical loss in magnetron life, but in practice this difference may not be as large as presumed. Furthermore, the half-wave option offers other advantages including lower cost.

References:

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